INDOOR AIR QUALITY ASSESSMENT

Lincoln D. Lynch School
30 Forest Street
Middleborough, MA 02346

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality at the Lincoln D. Lynch School (LDLS), 30 Forest Street, Middleborough, Massachusetts. The assessment was prompted by concerns of general indoor air quality and pediatric asthma. On January 30, 2006, a visit to conduct an indoor air quality assessment at the LDLS was made by Sharon Lee, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Ms. Lee was accompanied by John Retchless, Assistant Superintendent, Middleboro Public Schools, and Virginia Levesque, Principal, LDLS, for portions of the assessment.

The LDLS is a single-story brick building constructed in 1937. Basement areas were renovated and converted to classrooms and a cafeteria in 1957. It appears that the majority of building materials (e.g., floor tiles, heating and ventilation components) are original. Windows throughout the building are openable.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo

Ionization Detector (PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The school houses approximately 230 pre-kindergarten and kindergarten students with approximately 30 staff members. Tests were taken under normal operating conditions, and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in all areas surveyed, indicating inadequate air exchange throughout the school. Fresh air in classrooms is supplied by unit ventilator (univent) systems (Picture 1). A univent is designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and return air through an intake located at the base of the unit (Figure 1). Fresh and return air are mixed and filtered, then heated and provided to classrooms through an air diffuser located in the top of the unit. Univents were operating in all but one area. Obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks in front of univent returns, were seen in a few classrooms (Picture 3). In order for univents to provide fresh air as designed, units must remain free of obstructions and allowed to operate as designed.

As previously indicated, mechanical ventilation equipment in all areas is original. While the majority of univents were operating at the time of the assessment, it did not appear that sufficient fresh air was being provided to classrooms. This may indicate that fresh air is not provided continuously or that dampers within the univents were closed. In addition, a fan belt to one of the univents was loose. One building occupant expressed concerns regarding black debris expelled by the classroom univent; the most likely source of this material is particulate from a deteriorating fan belt, or possibly a saturated air filter. Equipment of this age is often difficult to maintain, especially since parts are not often readily available.

It appears that exhaust ventilation was originally provided to classrooms via gravity exhaust vents; however, this system has been abandoned. Ductwork within the building once allowed air to be drawn from classrooms via a "cubby" opening in the wall (Picture 4). A louver located inside the duct controls airflow. Heating elements within the ductwork create airflow via rising heat, a condition known as "the stack effect". Under the current circumstances, it appears that the building does not have a functioning exhaust ventilation system. Without sufficient supply and exhaust ventilation, normally occurring environmental pollutants can build up and lead to air quality/comfort complaints. In one room, the wall opening was sealed (Picture 5). If not in use, consideration should be given to sealing all exhaust vents to prevent backdrafting and movement of materials into occupied areas.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room.

It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment. Please note that several components of the mechanical ventilation system cannot be balanced in their current condition.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 ppm. Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from 67 ^{o} F to 71 ^{o} F, which were within or slightly below the MDPH recommended comfort guidelines in some areas. The MDPH recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., exhaust system sealed/abandoned).

The indoor relative humidity measurements ranged from 34 to 55 percent, which were within or close to the lower end of the MDPH recommended comfort range. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

The building has experienced problems with water penetration in basement level areas over the past year. According to Mr. Retchless, water typically would enter near windows along the west/northwest exterior wall during heavy rains. Damaged materials were removed and replaced and carpets were cleaned and dried. No current evidence of damage was observed at the time of assessment.

During a perimeter assessment of the LDLS, CEH staff observed moss growth along windows and the building exterior. Such growth indicates moisture is being retained in these areas (Picture 6). CEH staff also observed leaves and other debris gathered at the base of fire escapes (Picture 7) and plant growth against the building exterior. During heavy rains, these materials can prevent proper drainage. The growth of plant roots against exterior walls can bring moisture in contact with the foundation. Plant roots can eventually penetrate, leading to cracks and/or fissures in the sublevel foundation. Over time, this process can undermine the integrity of the building envelope, providing a means of water entry into the building via capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001). Freezing and thawing during winter months can create further damage. Additional breaches were also noted in the building exterior (Picture 8), which can serve as sources for water penetration.

Water damaged ceiling tiles were observed in a number of areas (Picture 9). Water damaged ceiling tiles can indicate that plumbing or roof leaks may exist in the building. Water-damaged ceiling tiles can provide a source for mold and should be replaced after a water leak is discovered and repaired. In one classroom, damage was also observed in areas above water damaged ceiling tiles at the junction where the window frame meets the exterior wall (Picture 10). Such damage would indicate that a breach exists in this area, allowing water to penetrate the building.

A water cooler was observed on carpeting (Picture 11). Overflow or spillage can moisten carpeting. Catch basins that hold water should also be emptied and cleaned regularly to prevent mold growth and associated odors.

Lastly, plants were noted in several classrooms; some were placed in close proximity to univents (Picture 3). Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen or mold.

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were 5 ppm. Carbon monoxide levels measured in the school ranged from 1 to 4 ppm, which were below outdoor levels (Table 1). Please note, outdoor carbon monoxide readings may result from the school's location to some heavily frequented roads, as well as its proximity to a parking lot, where cars are likely to idle.

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter (μg/m^3) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 μg/m^3 over a 24-hour average (US PEA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 8 μg/m^3. PM2.5 levels measured indoors ranged from 4 to 22 μg/m^3 (Table 1), below the NAAQS of 65 μg/m^3. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC measurements throughout the building were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While no measurable TVOC levels were detected in the indoor environment, VOC-containing materials were noted. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Cleaning products were observed on countertops and beneath sinks in a number of classrooms. Cleaning products contain VOCs and other chemicals, which can be irritating to the eyes, nose and throat and should be stored properly and kept out of reach of students.

Accumulated chalk dust was seen in chalk trays of some classrooms. Chalk dust is a fine particulate that can easily become aerosolized, irritating eyes and the respiratory system.

Consideration should be given to increasing frequency of chalk tray cleanings to prevent accumulation.

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks (Picture 3). The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to prevent excessive dust build up. A number of personal fans also had accumulated dust. Fans can aerosolize dust accumulated on fan blades when activated.

An insect nest was observed suspended from the ceiling tile system (Picture 12). Breaches in continuity to a ceiling tile system can allow dirt, debris and other materials into occupied areas. Nests can contain bacteria and may also be a source of allergenic material. Nests should be placed in resealable bags or containers to prevent aerosolization of allergenic material.

Lastly, an exterior intake vent was sealed with a wooden board and fiberglass insulation. The insulation can become a source for microbial growth and odors. These odors and moisture can penetrate the building if the vent is not sealed on the interior side of the building. The insulation material should be removed, and the vent should be resealed if not in use.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers.t
2. Operate all ventilation systems that are operable throughout the building (e.g., cafeteria, classrooms) continuously during periods of school occupancy and independent of thermostat control. To increase airflow in classrooms, set univent controls to "high".
3. Remove all blockages from univents to ensure adequate airflow.
4. Consider restoring exhaust system or installing motors utilizing existing ductwork to provide mechanical exhaust.
5. As a temporary measure or if restoration is not feasible, exhaust vents/shafts should be sealed in classrooms, as well as their termini (e.g., roof, basement) to prevent the migration of debris into occupied areas.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate

arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

7. Ensure roof/plumbing leaks are repaired, and replace any water stained ceiling tiles. Examine the areas above and around these tiles for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
8. Seal breaches in the building exterior to prevent water intrusion, drafts and/or pest entry. Consider repointing building.
9. Remove debris/plants growing around the perimeter of the building to prevent pooling and subsequent water penetrating to the building.
10. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.
11. Relocate or place tile or rubber matting underneath water coolers in carpeted areas. Clean and disinfect reservoirs as needed to prevent microbial growth.
12. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
13. Store cleaning products properly and out of reach of students. Consider placing cleaning products in cabinets with child safe locks. Ensure bottles are properly labeled.

14. Place nests in resealable containers or bags to prevent aerosolization of allergenic materials.
15. Refrain from suspending items from the ceiling tile system to prevent movement of particles into occupied spaces.
16. Remove insulation from vent, and ensure it is sealed from both the interior and exterior walls.
17. Consider adopting the US EPA (2000b) document, “Tools for Schools”, to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.
18. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH’s website at http://mass.gov/dph/indoor_air

References

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Picture 1

Classroom univent

Picture 2

Univent fresh air intake

Picture 3

Univent surrounded by items, note plants near univent diffuser

Picture 4

“Cubby” exhaust used as storage

Picture 5

Sealed “cubby” exhaust

Picture 6

Moss growth between brick exterior and window ledge

Picture 7

Debris gathered at base of building exterior

Picture 8

Breach between two facing exterior walls

Picture 9

Water damaged ceiling tiles

Picture 10

Water damaged ceiling tile near window, note staining above ceiling tile

Picture 11

Water cooler on carpeted floor

Picture 12

Insect nest suspended from ceiling tile system

Picture 13

Insulation used to seal vent

Lincoln D. Lynch School | **Indoor Air Results**

30 Forest Street, Middleborough, MA 02346 | **Date: 1/30/2006**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background	0	41	88	501	5	ND	8	N			Slight wind and rain.
basement side classroom	21	71	36	1405	3	ND	15	Y # open: 0 # total: 5	N	N	Hallway DO
cafeteria	0	67	55	1166	4	ND	10	N	N	N	
nurse's office	1	69	37	1557	1	ND	9	Y # open: 0 # total: 3	N	N	Hallway DO
small group classroom	3	70	36	1235	2	ND	4	Y # open: 0 # total: 2	Y univent	N	CD, DEM, PF, black particles from univent.
teachers' lounge	0	68	36	1167	2	ND	12	Y # open: 1 # total: 2	N	N	Hallway DO, bubbler on carpet.
1	20	71	36	1433	2	ND	9	Y # open: 0 # total: 3	Y univent	N	Hallway DO, CD.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium
AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials
design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile
NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings
sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

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									Supply	Exhaust	
2	18	70	37	1377	2	ND	9	Y # open: 0 # total: 4	Y univent	N	Hallway DO, CD, DEM, PF, items.
3	17	70	38	1462	2	ND	13	Y # open: 1 # total: 3	Y univent (off) items plant(s)	N	Hallway DO, CD, items, items hanging from CT, nests, plants.
4	1	70	36	1254	2	ND	7	Y # open: 2 # total: 4	Y univent furniture plant(s)	N	Hallway DO, CD, PF, aqua/terra, plants.
6	19	71	36	1528	2	ND	9	Y # open: 0 # total: 4	Y univent plant(s)	N	Hallway DO, CD, DEM, DEM odors.
7	20	71	32	1585	2	ND	11	Y # open: 2 # total: 4	Y univent	N	Hallway DO, #WD-CT: 4, DEM, fan belt loose.
8	21	71	36	1735	2	ND	12	Y # open: 0 # total: 4	Y univent	N	Hallway DO, CD, PF, FC re-use, items hanging from CT.

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									Supply	Exhaust	
10	20	69	42	1303	3	ND	10	Y # open: 1 # total: 4	Y univent (off) items	N	
11	11	69	41	1227	3	ND	8	Y # open: 0 # total: 4	Y univent	N	Hallway DO, PF, cleaners, food use/storage, items.
12	12	71	37	1483	2	ND	22	Y # open: 0 # total: 4	Y univent	N items	Hallway DO, high Pm2.5 from kids in motion; sandbox in room.

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